FESHM 6020.3: STORAGE AND USE OF FLAMMABLE GASES

Revision History

Author	Description of Change	Revision No. & Date
Richard Schmitt & Jim Priest	Revision 1, Modified risk class 0 and risk class 1 requirement to be compatible with FESHM 5031.1 and design practices; Applied FESHM format Template; Incorporated Fire Department to review process; Added Engineering Note to definitions; Changed Fire Safety Subcommittee to Fire Hazard Subcommittee; Replaced PPD Engineering contact information with document links; Renamed Table 1 from Figure 1 to match text reference in flow chart; Added requirement 12 in Section 6.1 regarding piping design; Added Requirement 13 in Section 6.1 regarding PVC vent piping; Relocated pipe joints from Section 6.2, 3 to 2.,f; Changed provision for leak testing from 90% to 125% in Section 6.2, 4; Changed chemist to SSO in Section 6.2, 14.	January 2013
Jim Priest	Revision 0, Initial release Chapter 6020.3	March 2008

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1.0 INTRODUCTION

The use of flammable gases in physics experiments presents a unique type of installation, requiring special considerations. In many cases, mixing of gases is involved. Large volumes of gases may be present; consequently even small leaks or ruptures of thin windows may cause incursions into the flammable concentration region with a large enough inventory to support a fire. Some flammable gases may be stored in the liquid state, increasing the inventory. Electrical equipment is an integral part of such installations and can therefore, provide an ignition source if improperly designed, fabricated, and/or operated. The purpose of this chapter is to mitigate the hazards associated with storage and use of flammable gases.

This chapter is intended to apply to activities using flammable gases, whether part of approved experiments taking beam or in testing labs and shops located across Fermilab. This chapter excludes gasses used as fuels, gasses used for welding, burning and brazing procedures and transportation of compressed gasses addressed by other chapters. It also excludes liquid hydrogen targets and the area immediately around them; however, does not exclude hydrogen storage or piping outside the tent or immediate vicinity of the target if there is no tent.

Compliance of all flammable gas system components with other relevant mandatory Fermilab ES&H Chapters is required. If the amount of flammable gas stored at any single location exceeds 10,000 pounds the requirements of OSHA part 1910.119, Process Safety Management of Highly Hazardous Chemicals, shall be followed.

2.0 REFERENCES

- 29 CFR 1910.119, entitled Hazardous Materials
- NFPA 58, Liquefied Petroleum Gas Code, 2011 Edition
- NFPA 70, National Electrical Code, 2005 Edition
- Fire Protection Guide to Hazardous Materials, Fourteenth Edition (NFPA 325M)
- FESHM 5031 – Pressure Vessels
- FESHM 5031.1 Piping Systems
- FESHM 5034 – Pressure Vessel Testing
- FESHM 5064 – Oxygen Deficiency Hazards (ODH)
- FESHM 6010 - Elements of the Fire Protection Program
- FESHM 6013 – Facility Incident Reporting Utility System (FIRUS)

3.0 DEFINITIONS

- **BSS Fermilab's Fire Department** – Individuals of an organization trained and tasked with emergency care, preventing, and extinguishing fires, and other emergency responses, such as ODH.
- **Engineering Note –** Typically includes design calculations and manufacturers data reports, allows a reviewer to check the design, fabrication, and installation. For further information reference http://esh.fnal.gov/xms/Engineering-Notes .
- **Fire Protection Engineer (FPE)** - Highly trained and educated professional responsible for overseeing the overall implementation and development of the Fermilab fire protection systems.
- **Fire Hazard Subcommittee (FHS)** – Subcommittee of the Fermilab ES&H Committee is delegated the Authority Having Jurisdiction (AHJ) for fire safety, life safety aspects of facilities, processes and experiments, and flammable and compressed gas systems.
- **FIRUS - Facility Incident Reporting and Utility System** - Lab-wide system that monitors building fire alarm systems and provides alarms at the Communications Center in Wilson Hall.
- **Landlord** - The Division/Section/Center (D/S/C) responsible for the facility or space where work is planned or occurring.

- **Senior Safety Officer (SSO)** - An individual who is assigned duties as the principal ES&H advisor to the division/center/section head.
- **Users/Experimenters** – Individuals responsible for maintenance and operation of an experiment.

4.0 RESPONSIBLILITIES

4.1 Division/Section/Center Heads (D/S/C)

- Assuring that the requirements of this chapter are met.
- Assuring that any flammable gas used in an experiment is reviewed and approved for its use, the experiment set up, and the effect on other experiments and the building.

4.2 ESH&Q Section

- Responsible for providing consultative support as chair of the Fire Safety Subcommittee.

4.3 Fire Hazard Subcommittee (FHS)

- Reviewing and recommending approval of risk classification to the D/S Head
- Reviewing and recommending approval of equivalent methods

4.4 ESH&Q- Fire Protection Engineer (ESH&Q-FPE)

- Responsible for the overall integration of fire protection and detection systems. This includes chairing coordination meetings amongst all responsible parties.
- Chairing the FIRUS meetings. Spokesperson for the FIRUS Team to FNAL Management.

4.5 Users/Experimenters

1. Complying with the instructions in this chapter pertaining to the installation, testing, maintenance and storage and use of flammable gas systems.
2. When FIRUS alarms are required, complete Message request form found in FESHM 6013..

5.0 PROGRAM DESCRIPTION

Flammable gases may be diluted with inert gas to the point where the mixture is not flammable. This chapter does not apply to facilities using only non-flammable mixtures. The flammability of a mixture can be determined by referencing Bureau of Mines Bulletins 503 and 627 at http://www.osti.gov/bridge/servlets/purl/7328370-wx68Fy/ and http://www.osti.gov/bridge/servlets/purl/7355338/.

5.1 Gas Storage and Usage Facilities Rick Classification

A risk analysis shall be conducted using the chart shown in Figure 1. The analysis is based on the energy in the gas available for a fire. The chart in Figure 1 utilizes the limits on quantities of hydrogen gas. These quantities must be adjusted for other gases using the heat of combustion as described in Appendix 4. The results of the analysis indicate the Risk Class as described in Table 1. Examples of Risk Class analyses are given in Appendix 1.

Table 1 - Risk Classes

Risk Class 0	Risk of a small local flash fire
Risk Class I	Risk of a local fire
Risk Class II	Risk of a general fire

- The upper limit for a Risk Class 0 is the combustion energy in 0.6 kg of hydrogen. The equivalent quantities of some typical flammable gases are given in Table 2. This equivalence is scaled according to the heat of combustion of the gas.

Table 2
Maximum Quantities of Flammable Gases Meeting Criterion for Risk Class 0

Description	Mass (kg)	Mass (SCF)
Hydrogen	0.6	250
Deuterium	1.2	250
Methane	1.5	80
Ethane	1.7	50
Propane	1.7	30
Isobutane	1.8	25
Dimethyl Ether	2.7	30

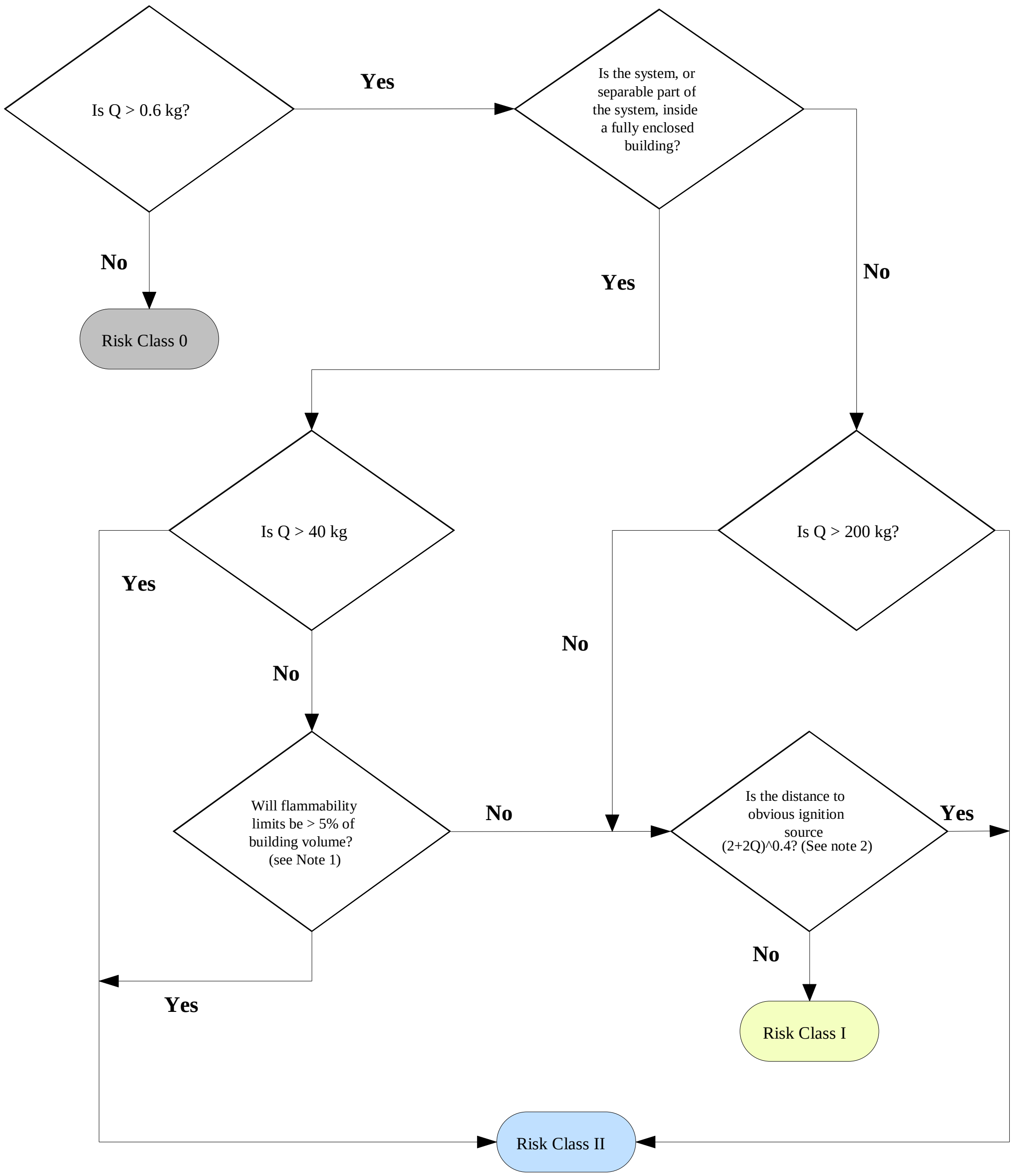
- Installations may be subdivided into separable parts if restrictions exist to keep the gas flow from one part to another from exceeding ten times the normal flow rate. Normally, the separable parts will be in physically separate rooms. The Risk Class shall be determined for each installation or separable part thereof using Figure 1.

- Gas in cylinders connected to a piping system is included in the quantity calculation. Nearby stored gas may be excluded from the quantity calculations if the stored quantity is less than the amounts listed in Table 2 for risk class zero.

- If the Risk Class is not determined by a written analysis, then a default assignment of Risk Class II will be chosen.

- Before using the flowchart in Figure 1, evaluate the total gas inventory in terms of the hydrogen equivalence Q using the heat of combustion as a scaling parameter. The system may be separated into parts each with its own risk classification. For storage facilities, the value of Q is determined in all containers. For systems in which the gas is not in storage, the inventory is the sum of the mass present including detectors, piping, and manifolds.

Figure 1 - Risk Classification Flow Chart



Note 1: ***Ventilation should be considered for accidental venting of gas, including "worst case" scenarios such as the rupture of one or more detectors with discharge of their inventory. See text for consideration of "steady state" leaks. For storage facilities, this should consider the worst case such as the dumping of one full gas container. In some systems a credible accident may have to include the dumping of several cylinders manifold together.***

Note 2: ***Ignition sources include arcing devices, electrical equipment not rated Class 1 Division 2 locations per NEC article 500, welding, grinding, open flames, etc. For storage facilities, consider the worst case such as the dumping of one full gas container.***

5.2 Procedures for Approval

- Risk Class 0
  The risk analysis shall be reviewed by the Fire Hazard Subcommittee (FHS) or by an independent reviewer appointed by the Division/Section head. A copy of the independent review shall be sent to the FHS. Approval by the Division/Section head is required before the introduction of flammable gas into a system.

- Risk Classes I and II
  The risk analysis and the installed system shall be reviewed by the FHS or by an independent reviewer appointed by the Division/Section head. A copy of the independent review shall be sent to the FHS for concurrence that the requirements of this chapter have been met. Approval by the Division/ Section head is required before the introduction of flammable gas into a system.

- Nothing in this Chapter is intended to prevent the use of methods or materials of equivalent or superior quality to those prescribed below. The Fire Hazard Subcommittee will review documented requests for equivalency.

6.0 FLAMMABLE GAS INSTALLATION REQUIREMENTS

6.1 Risk Class 0 Installations

1. The area shall be posted "Danger-Flammable Gases, No Ignition Sources" using standard signs available from the Fermilab ESH Section. A list of responsible persons with their phone numbers shall also be posted.

2. Combustibles and ignition sources shall be minimized within three meters of gas handling equipment, piping or apparatus.

3. A pressure regulator appropriate for the gas and its environment shall be used.

4. An orifice, excess flow valve or other fixed means of limiting the flow to no higher than ten times the maximum operational flow rate shall be installed.

5. All gas cylinders shall be secured. Cylinders not in use shall be capped. Empty cylinders shall be promptly removed. Adequate hardware for securing all cylinders used or stored shall be available.

6. Enclosed volumes containing piping or equipment shall be incapable of becoming pressurized. For example, chest freezers shall not have latching doors. Electrical devices enclosing or enclosed within these volumes shall be listed for use in Class 1, Division 2 locations per NEC article 500 or otherwise be documented and approved as non-sparking devices.

7. Leaks from experimental devices such as drift chambers shall be measured and documented prior to initial operation (with nonflammable gas, if possible). Leakage above seven liters/hour from any one chamber shall be mitigated. Recheck for leaks after major repairs or modifications, and at least every twelve months. If the aggregate leak rate is constant individual detectors do not need to be checked. Leakage exceeding 20% of the lower explosive limit at a distance over two inches from an identified "point" leak shall be repaired.

8. Ventilation above one air change per hour shall be maintained in areas using or storing flammable gas. This may be accomplished by mechanical or natural ventilation. For natural ventilation, a room vent with a minimum of 1/2 square foot free area shall be provided per 1000 cubic feet of room volume.

9. Welding burning, brazing, and grinding permits shall not be issued for areas within ten meters of the equipment containing flammable gas unless approved in advance by the responsible D/S Head or designee.

10. Oxidizers shall be stored separately from flammable gas containers or combustible materials. Either a distance of 20 ft (6.1 m) or a noncombustible barrier at least 5 ft (1.5 m) high having a fire resistance rating of at least ½ hour is a minimum separation requirement.

11. Detector systems shall be purged with inert gas prior to introducing flammable gas. Provide sufficient purging prior to allowing high voltage to the detectors.

12. A piping engineering note may consist of certification that:
    a. Metallic tubing is 0.625 inch or less OD and the design pressure is 100 psig or less
    b. Non-metallic tubing has a design pressure of 15 psig or less

13. Vent piping may use PVC material if all of the following conditions are met
    a. One end of the piping is open to the atmosphere
    b. Pressure during maximum flow conditions does not exceed 1 psig at any point in the line
    c. The vented gas contains no liquid or solid particles

6.2 Risk Class I Installations

Risk Class I installations are subject to the Risk Class 0 requirements, as well as the following requirements:

1. The system, including vessels, chambers, supply and vent piping, and exhaust points shall be labeled "flammable gas".

2. Piping requirements: Exceptions to this paragraph are permitted adjacent to experimental apparatus where needed for flexibility, electrical isolation, repairs or because of congestion. This exception is limited to within five meters of the normal operating position.
    a. Piping and fittings shall be protected from mechanical damage.
    b. Piping shall be rated for the expected temperature and pressure.
    c. Supply piping shall be metallic.
    d. Piping shall be supported in a substantial and workmanlike manner.
    e. Piping shall not be installed inside cable trays with electrical conductors.
    f. Joints shall be made by brazing, pipe thread, or commercial fittings appropriately installed. Custom-made fittings required by detector design shall provide secure connections.

3. Refer to FESHM 5031.1 for piping requirements. Larger or higher pressure systems require a formal piping note per FESHM 5031.1. For smaller piping systems the note may consist of certification that:
    a. All items in paragraph 2 above are met.
    b. Metallic piping is 0.625 inch OD or less with a design pressure of 100 psig or less.
    c. Any non-metallic piping has a design pressure of 15 psig or less.

4. The entire piping system shall be pneumatically tested for leaks at 1.25 times the design pressure per Chapter 5034 of the Fermilab ES&H Manual.

5. Bubblers, flow meters and other instruments shall be securely mounted and protected from possible breakage.

6. The system shall be purged with inert gas prior to the introduction of flammable gas. If vacuum pumps are used for this, they shall be listed for flammable gas service.

7. Pressure relief devices shall be provided to limit the pressure to the maximum working pressure in various parts of the system. In the case of low pressure equipment, dedicated bubblers may be used as relief devices. Common exhaust piping shall not be used if equipment overpressure could result due to built up back pressure.

8. Relief devices in flammable gas service with a capacity over two standard liters per minute shall be vented outdoors. The exhaust locations shall be chosen to minimize fire hazards and shall not be within three meters of an air intake. Vents shall be protected from clogging by debris, snow or ice. Inspection and Testing of the primary relief valves shall be included in the Engineering Note.

9. Flammable gas detectors shall be installed near equipment installations, mixing stations, and in storage sheds:

   a. A high level alarm shall be installed and set no higher than 20% of the lower explosive limit (LEL) to summon the Fire Department through the FIRUS system. (Local alarms at a lower percentage of LEL may be used to initiate corrective action.)

   b. A high level alarm shall automatically shut off the supply of flammable gas and turn off power to potential ignition sources within three meters of operative gas usage apparatus.
   c. "Crash buttons" shall be provided to accomplish the shutdowns described in b. These devices shall be conveniently located, and one shall be adjacent to the fire alarm panel, if present. Crash buttons shall be labeled "Gas System and Experiment Power Shutdown". They shall be shown on the Building Hazard Maps.
   d. Automatic restart of flammable gas systems and power sources shall not be allowed after a high level alarm. This restriction is intended to require a safety assessment of the situation. In case of an alarm follow the local emergency plan.

10. Visual indication of the actual use of flammable gas shall be provided at both the storage location and at the experimental apparatus. Such indicators shall be controlled automatically and shall indicate actual "gas on" and "gas off" status in real time. Flammable gas alarm status shall be also displayed at the locations of these warnings.

11. Possible Oxygen Deficiency Hazards shall be addressed according to FESHM Chapter 5064. The hazard shall be considered for each building, room, used for storing/processing flammable and/or inert gas.

12. The following documentation shall be provided to the FSH, and all applicable Division/Center/Section safety subpanels if convened, and a copy kept at the system site.

    a. A general description of the system, including the types of gases to be used.
    b. An accurate piping and instrument diagram with symbols per ISA S5.1 (Instrument Society of America), including the normal set point of regulators.
    c. An instrument and valve summary.
    d. A plan view of the installation including the locations of flammable gas detector heads.
    e. Procedures for normal and abnormal operations including purging, startup, gas bottle changes, mixing, leak detection, tests, alarms, shutdown, emergency situations and ventilation.
    f. Documentation and/or test results demonstrating the adequacy of the pressure relief system.
    g. A call list, including off-hours telephone numbers and/or available pager numbers, of personnel familiar with the operation of the system, in accordance with FESHM 6013.
    h. A summary of leak test measurements.

13. The Fire Department shall be notified of actual gas startup and system shutdown.

14. The D/S/C SSO shall be notified before using any types of gas not found in the stockroom.

6.3. Risk Class II Installations

Risk Class II installations are subject to the Risk Class 0 and I requirements, as well as the following requirements:

1. Storage and processing enclosures shall be constructed, where practical, to comply with the guidelines of Chapter 7 of NFPA-58 (Appendix 2). While this document is specifically applicable only to LP gas storage facilities, it is a useful guide. Exceptions may be made with the approval of the Fire Hazard Subcommittee.

2. In addition:

   a. All storage enclosures shall be maintained free of standing water and/or ice to prevent falls of personnel handling gas system components.
   b. Permanent racks and securing equipment shall be available for cylinder storage.

c. Windows in gas sheds shall be wire glass set in metal frames with a fixed sash.

d. Enclosures near areas of vehicle access shall be protected with bumper posts.

e. Flammable gas enclosures shall not be used to store oxidizers or gases used as fuels shall be prohibited. These enclosures shall not be used to store items not relevant to the gas system.

f. Electrical installation shall comply with NEC Article 500, Hazardous (Classified) Locations. The classification guidelines are shown in Appendices 5 and 6.

g. There shall be provisions for the ventilation of such enclosures per NFPA-58 (Appendix 2). Mechanical ventilation failure shall be alarmed.

3. The use of line-regulators downstream of cylinder regulators is strongly encouraged.

4. Fire sprinklers shall be installed in accordance with NFPA 13 to protect any adjoining or enclosing buildings from a fire in the gas storage facility. Sprinklers shall not be installed within the gas storage facility itself since it is not desirable to quench a gas fire with the leak still present.

APPENDIX 1: EXAMPLES OF RISK CLASS DETERMINATION

This appendix provides examples of Risk Class determination using Figure 1 and requirements of this chapter. The first step in such an analysis is to determine the inventory in terms of hydrogen content and then to follow the Figure 1 flowchart to determine the Risk Class. In many cases, the presence of flow and/or pressure restrictions may permit the facility to be separated into constituent parts which may be assigned different Risk Classes.

SUBDIVISION OF A SYSTEM

Figure 1A below is an illustration of a typical facility amenable to such separability. The storage area is an attached building separated from a processing area which is, in turn, separated from the experimental area. The processing area could, for example, contain mixing apparatus or temperature regulation equipment. One could, of course, have the processing area included within either the storage area or in the experimental hall. Each installation will differ, however generally solid walls with appropriate ventilation controls are required along with the limitations on the gas flow to render areas separable.

In this figure a system is shown in which two different gases (designated by different cross-hatching) are used to supply various detectors. Important details such as bubblers, check valves, orifices, shutoff valves, and gas detectors are not shown. Note that the storage area contains several cylinders in "off-line" storage. After passage through the detectors, the gases are vented to the outdoors at the right of the figure. The precautions of this policy are dependent upon the nature and size of the entire complex including all flammable gases present, even if there are independent systems supplying different detectors, or even different experiments in the same building.

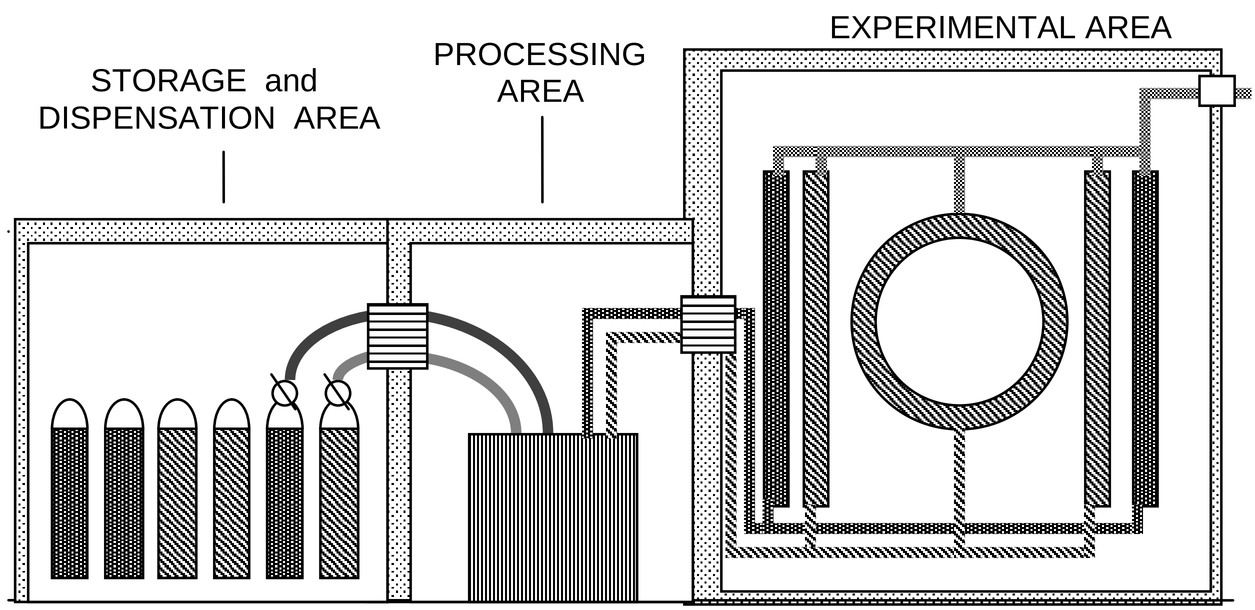


Figure 1A Typical Flammable Gas Installation

EXAMPLES OF RISK ASSESSMENT

Example 1

Two 81 SCF cylinders of a 50-50 mixture (by volume) of argon-ethane (Fermilab stock catalog number 1980-1095) will be used in a room whose volume is 9*15*20 ft^3 (2700 ft^3). This room, inside a larger building, contains no obvious fire hazards such as welding operations. The gas is to be supplied to drift chambers.

First, to determine Q, it is recognized that only 40.5 SCF of a given cylinder is ethane. Thus, from Appendix 3 and Appendix 4;

$Q = 2*40.5\ ft^3 *0.028(m^3/ft^3)*1.26(kg/m^3)*0.36(H_2$ equivalence factor)

Q = 1.03 kg hydrogen equivalent inventory

Thus by box 1 in the flowchart, we exceed the limit for Risk Class 0 and must go to box 2. Continuing to box 2, we find the answer to be yes but the answer to the question in box 3 is negative. Doing the calculation prescribed in box 4 we find that 5% of 2700 ft^3 is 135 ft^3. Dividing 81/135 finds a maximum concentration of 60 %, which exceeds the flammability upper limit. Thus, any concentration below this limit is reachable with the available inventory, since no inventory controls have been specified. Therefore the answer to this question is affirmative and the Risk Class is II. If only a single cylinder was needed, the Ø.5 kg hydrogen equivalence would have rendered a Risk Class 0 determination.

Example 2
This example is the same as that explored in example one except that these two cylinders are used to test a drift chamber in an open experimental hall 60*200*30 = 360,000 ft^3. The nearest ignition source is a temporary brazing operation at a distance of 40 ft (12.2 m). Following the flow chart, the same path is found until box 4 is reached. Five percent of this much larger room volume is 18,000 ft^3. Thus the maximum concentration in this volume would be 1.5 %, so that this question is answered negatively. At box number 6, we determine that objects or operations presenting an ignition hazard (the brazing operation) are more distant than the 2.0 m required by the formula based on the hydrogen equivalent quantity. Thus the Risk Class is I.

Example 3
A large system having an inventory of 15 cylinders such as used in the first two examples is stored in a separate "gas room" and is connected to a drift chamber system in the same experimental hall as in example 2. The same brazing operation is continuing. There is no processing area, only a storage area and the experimental hall. The inventory of the storage area is 15*0.5 kg/cylinder = 7.5 kg hydrogen equivalent. For the storage area a "yes" is encountered at box 2 while a "no" is encountered at box 3. The volume of the storage room is only 6*10*8 = 480 ft^3(13 m^3), however the gas inventory corresponds to a volume of 608 ft^3. Thus, without considering ventilation, the storage area will be Risk Class II after the query of box 4. Continuing on to the experimental hall the interconnection is considered. If appropriate flow restrictions exist, one may only have to consider Q to be the volume of detectors plus piping in the hall. Thus it may be appropriate to declare the experimental hall to be Risk Class I, if the condition on the distance from obvious ignition sources is met at box 6. If the detector volumes are large, then box 4 may indicate Risk Class II.

APPENDIX 2: CHAPTER 10 of NFPA-58

Code for the Storage and Handling of Liquefied Petroleum Gases

Chapter 10 Buildings Or Structures Housing Lp Gas Distribution Facilities

Chapter 10 Buildings or Structures Housing LP-Gas Distribution Facilities

10.1 Scope.

10.1.1 Application. This chapter applies to the construction, ventilation, and heating of structures, parts of structures, and rooms housing LP-Gas systems where specified by other parts of the code.

10.1.2 Nonapplication. This chapter does not apply to buildings constructed or converted before December 31, 1972.

10.2 Separate Structures or Buildings.

10.2.1 Construction of Structures or Buildings.

10.2.1.1 Separate buildings or structures shall be one story in height and shall have walls, floors, ceilings, and roofs constructed of noncombustible materials.

10.2.1.2 Either of the following shall apply to the construction of exterior walls, ceilings, and roofs:

(1) Exterior walls and ceilings shall be of lightweight material designed for explosion venting.
(2) Walls or roofs of heavy construction, such as solid brick masonry, concrete block, or reinforced concrete construction, shall be provided with explosion venting windows that have an explosion venting area of at least 1 ft^2 (0.1 m^2) for each 50 ft^3 (1.4 m^3) of the enclosed volume.

10.2.1.3 The floor of separate structures shall not be below ground level.

10.2.1.4 Any space beneath the floor shall be of solid fill, or the perimeter of the space shall be left entirely unenclosed.

10.2.2 Structure or Building Ventilation. The structure shall be ventilated using air inlets and outlets, the bottom of which shall be not more than 6 in. (150 mm) above the floor, and ventilation shall be provided in accordance with the following:

(1) Where mechanical ventilation is used, the rate of air circulation shall be at least 1 $ft^3/min\cdot ft^2$ (0.3 $m^3/min\cdot m^2$) of floor area.
(2) Outlets shall discharge at least 5 ft (1.5 m) from any opening into the structure or any other structure.

(3) Where natural ventilation is used, each exterior wall shall be provided with one opening for each 20 ft (6.1 m) of length.

(4) Each opening shall have a minimum size of 50 in.^{2} (32,250 mm^2), and the total of all openings shall be at least 1 in.^{2}/ft^2 (6900 mm^2/m^2) of floor area.

10.2.3 Structure or Building Heating. Heating shall be by steam or hot water radiation or other heating transfer medium, with the heat source located outside of the building or structure *(see Section 6.22),* or by electrical appliances listed for Class I, Group D, Division 2 locations in accordance with *NFPA 70*, *National Electrical Code*.

10.3 Attached Structures or Rooms Within Structures.

10.3.1 Construction of Attached Structures.

10.3.1.1 Attached structures shall be spaces where 50 percent or less of the perimeter of the enclosed space is comprised of common walls.

10.3.1.2 Attached structures shall comply with 10.2.1.

10.3.1.3 Common walls of structures shall have the following features:

(1) A fire resistance rating of at least 1 hour

(2) Where openings are required in common walls for rooms used only for storage of LP-Gas, 1 $^1/_2$-hour (B) fire doors

(3) A design that withstands a static pressure of at least 100 lb/ft^2 (4.8 kPa)

10.3.1.4 Where the building to which the structure is attached is occupied by operations or processes having a similar hazard, the provisions of 10.3.1.3 shall not apply.

10.3.1.5 Ventilation and heating shall comply with 10.2.2 and 10.2.3.

10.3.2 Construction of Rooms Within Structures.

10.3.2.1 Rooms within structures shall be spaces where more than 50 percent of the perimeter of the space enclosed is comprised of common walls.

10.3.2.2 Rooms within structures shall be located in the first story and shall have at least one exterior wall with unobstructed free vents for freely relieving explosion pressures.

10.3.2.3 Walls, floors, ceilings, or roofs of the rooms shall be constructed of noncombustible materials.

10.3.2.4 Exterior walls and ceilings shall be of lightweight material designed for explosion venting.

10.3.2.5 Walls and roofs of heavy construction (such as solid brick masonry, concrete block, or reinforced concrete construction) shall be provided with explosion venting windows or panels that have an explosion venting area of at least 1 ft^2 (0.1 m^2) for each 50 ft^3 (1.4 m^3) of the enclosed volume.

10.3.2.6* Walls and ceilings common to the room and to the building within which it is located shall have the following features:

(1) Fire resistance rating of at least 1 hour
(2) Where openings are required in common walls for rooms used only for storage of LP-Gas, 1 $^1/_2$-hour (B) fire doors
(3) Design that withstands a static pressure of at least 100 lb/ft^2 (4.8 kPa)

10.3.2.7 Where the building to which the structure is attached is occupied by operations or processes having a similar hazard, the provisions of 10.3.1.3 shall not apply.

10.3.2.8 Ventilation and heating shall comply with 10.2.2 and 10.2.3.

APPENDIX 3: FLAMMABILITY LIMITS

Data from Fire Protection Hazardous Materials Handbook, includes NFPA 325M-1994

Fire Hazard Properties of Flammable Liquids, Gases and Volatile Solids

Gas	Density at NTP (kg/m^3)	Flammability Limits (percentage volume in air at NTP)		
Hydrogen*	0.0824	4.0	-	75.0
Deuterium*	0.180	5.0	-	75.0
Methane	0.668	5.0	-	15.0
Acetylene*	1.174	2.5	-	100
Ethane	1.26	3.0	-	12.5
Propane	1.87	2.1	-	9.5
Isobutane	2.49	1.8	-	8.4
Dimethyl Ether	1.95	3.4	-	27.0

*Not expected to be routinely used in detectors because of its large flammability range, included for reference only.

Cylinders are generally specified as containing a given number of standard cubic feet (SCF). The inventory may be estimated by using the above densities of the gas phase with the conversion 0.028 m^3/ft^3.

APPENDIX 4: HEATS OF COMBUSTION

Hydrogen equivalent, Q

The heat of combustion for other gases is used to determine the hydrogen equivalent mass, Q, for use in Figure 1 in the main text. For example the table indicates that ethane has 0.36 times the heat of combustion of hydrogen per unit mass. Therefore 1.7 kg of ethane is equivalent to 0.6 kg of hydrogen in determining Risk Class.

Heats of Combustion

The following table of heats of combustion may be useful for calculating hydrogen equivalents. The heats of combustion can be found in, for example, *The Handbook of Chemistry and Physics.*

Gas	Molecular Weight	Gross Heat of Combustion (kj/g)	Relative to That of Hydrogen
Hydrogen-H_2	2	143	1.00
Deuterium-D_2	4	72	0.50
Methane-CH_4	16	55	0.39
Acetylene-C_2H_2	26	50	0.35
Ethane-C_2H_6	30	51	0.36
Propane-C_3H_8	44	50	0.35
Isobutane-C_4H_{10}	58	49	0.34
Dimethyl ether-$(CH_3)_2O$	46	32	0.22

Appendix 5: ELECTRICAL CLASSIFICATION GUIDELINES

National Electrical Code Hazardous (classified) locations

General

The NEC Article 500 (NFPA 70) defines installation requirements for electrical equipment in hazardous areas. An NEC hazardous area is defined by Class, Group and Division.

Class

The Class designation defines the type of hazard, whether gas, dust or others. Locations where flammable gas is used are defined as Class 1.

Group

Group designation is determined by the type of gas. Hydrogen is in Group B and all remaining flammable gases normally used at Fermilab are Group D.

Division

The Division designation depends on the probability of flammable gas being present in the atmosphere. The requirements of Division 1 are more stringent than those in Division 2. Installation requirements for Division 1 areas are defined in the NEC, Article 501. Installation requirements for Division 2 areas are defined in the NEC, Article 502.

Area Classification

General Guidelines

These guidelines are based on common gas system installations at Fermilab. The classification shall be determined for each specific installation. The general plan for gas systems is that electrical devices will be kept out of Division 1 areas when possible. Division 2 is applicable when a flammable mixture is likely to be present less than ten hours per year.

Specific Location Classifications pertaining to Fermilab gas systems

1. Enclosed gas storage and mixing sheds are Division 2. This is based on adequate ventilation, this standard, and that a flammable mixture is likely to be present in the atmosphere less than ten hours per year.

2. A sphere with a diameter of 1.5 meters around outdoor vents is Division 1. A sphere with a diameter of 3 meters is Division 2.

3. A sphere with a diameter of one meter is Division 1 around indoor vents. A sphere with a diameter of two meters is Division 2.

Ignition Temperatures per NFPA 325M-1994

Ethane	472 C
Methane	537 C
Isobutane	460 C
Isopropyl Alcohol	399 C
Ethyl Alcohol	363 C